2007

The Impact of Laboratory Report Format on Student Learning

David Hoffa
David Hoffa Industrial Consulting

Steven A. Freeman
Iowa State University, sfreeman@iastate.edu

Int. J. Engng Ed. Vol. 23, No. 1, pp. 105–113, 2007
Printed in Great Britain.
0949-149X/91 $3.00+0.00

The Impact of Laboratory Report Format on Student Learning*

DAVID W. HOFFA
David Hoffa Industrial Consulting, PO Box 783, Ankeny, IA 50021, USA.
E-mail: dwhoffa@gmail.com

STEVEN A. FREEMAN
Department of Agricultural and Biosystems Engineering, Iowa State University, Ames, IA 50011, USA

This study sought to identify the effects on student learning of a brief 'synopsis format' laboratory report versus the lengthier 'traditional format' laboratory report. Fifty-six Iowa State University industrial technology students were randomized into one of two groups that were required to write five synopses followed by four traditional reports or vice versa. Latin Square Design analysis revealed no difference in exam scores between students who wrote synopsis reports versus those who wrote traditional reports. Exit survey results revealed that students preferred the synopsis format and perceived that the synopsis format required them to think more deeply about the content.

Keywords: synopsis; laboratory reports; Writing Across the Curriculum/WAC; writing; technical writing; professional/technical communication

INTRODUCTION

MANY INDUSTRIAL TECHNOLOGY PROGRAMS incorporate both a lecture component and a laboratory (lab) component in order to help students increase their understanding of the curriculum. Felder and Peretti [1] said, 'a basic tenet of learning theory is that people learn by doing, not by watching and listening. Engineering laboratory courses are consequently crucial to the learning and retention of engineering principles' (p. 1). Industrial technology accreditation requirements similarly emphasize the importance of laboratory experiences [2]. While some researchers [3–5] question the value of lab experiments, there is no doubt that the lab experiment is a commonly employed teaching tool in industrial technology. As Gillet *et al.* [6] stated, the purpose of laboratory experiments in industrial technology 'is to motivate, illustrate, and enlighten the presentation of the subject matter addressed in the lecture' (p. 190).

A written report of the experiment and its findings often follows the lab experiment in order to cause the student to reflect on, summarize, and quantify the laboratory experience. To learn by doing in the laboratory, followed by reflecting on that experience and writing about it in the form of a report, can only further enhance learning. Lederman [7] said 'the assumption that students are likely to learn the nature of science through implicit instruction (i.e. performance of scientific inquiry with no reflection on the nature of the activity) should be called into question' (p. 928). On the contrary, Drury *et al.* [8] found that students typically did not feel that writing assignments increased their understanding. A well-designed lab report asks a student to reflect on: the activity, the reading (assuming the reading assignment has been done), and the lecture content, and synthesize these three into a new, succinct document. These are the goals of the synopsis lab report format.

TRADITIONAL AND SYNOPSIS LABORATORY REPORTS

Traditional laboratory reports

The traditional lab report, for the purposes of this study, was defined as a report in which subjects may take as much space as they wish in order to report the information in Table 1. The traditional style of lab report is written chronologically, similar to other documents that have the purpose of reporting work. Doumont [9] said students 'present the reason for the work in an introduction (the before), detail this work in a body (the during), and report its outcome in a conclusion (the after)' (p. 166). For the purposes of this study, subjects were required to separate the conclusion into two separate sections: the discussion and the conclusion. The discussion section was the place to discuss the experiment, the procedures, and the results, while the conclusion was a brief section that attempted to tie the experiment to the curricular content.

While the experiment itself may be on the third (application) level of Bloom's (1956) Taxonomy of Educational Outcomes [10], the traditional lab

* Accepted 18 October 2006.

Table 1. Major headings required for traditional laboratory reports

Heading	Description
Title Page	A specific format was specified
Introduction	The student was to explain why the experiment was worth performing, what the intended outcomes were believed to be, and the perceived importance of the experiment. This section was to be written in the future tense.
Results	The student was to include the completed lab experiment handout as the results section. The results were graded for accuracy.
Discussion	The setup, procedures employed, measurements and results, and problems encountered with equipment or procedures of the lab experiment were to be discussed in detail in this section. This section was to be written in past tense.
Conclusion	The student was to conclude by summarizing the experiment and making an attempt to relate the lecture and reading of the lab. this section was to be written in the present tense.

report style promotes the reiteration of the experimental procedure and results and does not seem to encourage deep thought regarding the purpose of the experiment and its relation to the curriculum. Even though it was required in the paper guidelines, students rarely provided more than a few sentences of shallow critique; therefore, the writer of a traditional lab report operates at the second level (comprehension). At the comprehension level, students demonstrate their understanding of concepts by recalling what they have learned, translating and interpreting findings, and explaining expected and unexpected results [10, 11].

Synopsis laboratory reports

A synopsis report, in contrast, was restricted to a single page and focused on relating the content of the experiment to the curricular content. For example, if an experiment was performed on the electrical quantity of resistance, a synopsis should not have reported the results of any measurements taken during the experiment, but instead generically discussed the electrical property of resistance. The report was to be written in a style similar to an abstract or executive summary; it was to be written to an audience who wants to know the gist of the work that was performed, sparing the minutiae—a corporate Vice President, for example. The writer was not permitted to discuss experiment-specific material such as setup, procedures, or measurement results, and was to write in the passive voice and present tense [12].

The synopsis format ignores the before and during, focusing on the after, or conclusion. A synopsis is to be written devoid of all experiment-specific information and facts (such as problems encountered, measured results, and procedures) and requires the writer to think deeply about the purpose of the experiment as it relates to the theoretical concept(s) discussed in assigned readings and lecture content, and to synthesize these into a new, succinct document. While interpretations of Bloom's Taxonomy vary [10, 11], the recombination and summarization of readings, class discussions, and laboratory experiences to produce an original work seems descriptive of the synthesis level of the taxonomy.

GOAL OF THE STUDY

This study sought to discover whether students who wrote their lab reports in the synopsis format learned the course curriculum (in terms of comprehensive exam scores) as well as those who wrote their reports in the traditional style of the field of industrial technology.

Need for the study

Traditionally, lab reports in industrial technology are written in the 'introduction/results/conclusion' format, which is lengthy both for students to write and for instructors to grade. An exhaustive review of the literature has yielded no evidence of prior research concerning writing of lab reports in the synopsis format.

The literature repeatedly reflects the importance of teaching communication skills to students and industry's desire for graduates who have solid written communication skills [8, 13–23]. Some specific examples include:

- Nixon and Fischer [19] found that:

  [a] lengthy review of the curriculum in the College of Engineering at the University of Iowa, conducted from 1997 to 2000 made it apparent that subjects were not gaining appropriate communications skills from the curriculum. It was apparent from both advisory board input and from ABET [Accreditation Board for Engineering and Technology] concerns that steps were needed to address this lack (p. T2G/1).
- Doumont [20] said that 'it was a well-known complaint from real-world companies that the young graduates they hire were ill-prepared for . . . communicating in the workplace' (p. 138).
- Baren and Watson [21] also found a strong desire for engineering graduates with good communication skills (accreditation guidelines indicate the same desires for industrial technology students [2]):

  [a] cursory look through the classified section of any newspaper indicates that 'good communication skills' were a requirement of most companies which hire engineers. Campus recruiters, members of [Temple University's] industrial advisory committees, senior design industry advisors and other practicing engineers continue to emphasize the need for young engineers 'who can communicate' (p. 432).

- Boiarsky [22] said 'the need for engineering students to learn to communicate effectively has never been greater if they are to have the ideas they propose accepted.
- Lima, Drapcho, Walker, Bengtson and Verma [23] stated that 'a long-standing perceptual complaint from employers hiring entry-level engineering graduates is a lack of communication skills' (p. 67).

The synopsis format—a succinct, single page document that is written to a reader who needs an accurate summary of what has taken place (or in the classroom, what the writer has learned)—is a model taken directly from industry. According to Dr. John R. Wright Jr. [12], Associate Professor of Automation & Electronics Technologies at Millersville University of Pennsylvania and a former Technical Manager at TENERGY, L.L.C., and early proponent of the synopsis laboratory report format in industrial technology 'TENERGY's research and development personnel were required to produce 1–2 page synopses of our weekly research findings for review by management. A synopsis (at TENERGY, L.L.C.) was defined as an abbreviated briefing that attempts to summarize and disseminate key significant information to others as a communication tool.' The synopsis report is one method of bringing this type of writing into the curriculum and falls into the Writing in the Disciplines concept of the Writing Across the Curriculum movement that is underway on many university campuses [24, 25].

Writing Across the Curriculum

Writing Across the Curriculum (WAC) is a concept established in the 1980s in response to the perception that students were lacking in writing skills and that seeks to address this problem by incorporating discipline-specific writing in the curricula of non-English courses [26, 23]. WAC activities in the classroom can be categorized as Writing to Learn (WTL) or Writing in the Disciplines (WID). WTL is summarized by Romberger [25] as an

> approach to WAC [that] frequently makes use of journals, logs, microthemes, and other, primarily informal, writing assignments. If [students] write reactions in their own words to information received in class or from reading, students often comprehend and retain information better. Also, because students write more frequently, they either maintain or improve their writing skills and avoid a decrease in writing ability from entrance to senior year (Writing to Learn section).

On the other hand, WID 'is premised on the idea that students become better readers, thinkers, and learners in a discipline by [writing in] the forms and conventions specific to it' [24, p. 19]. Article and book reviews, annotated bibliographies, literature reviews, research papers, and laboratory reports are the types of assignments a WID-focused course might include.

METHODOLOGY

Population and sample

The population of this study was undergraduate industrial technology majors at Iowa State University. The convenience sample contained the students who enrolled in ITEC 140, Electrical Fundamentals, in the Fall 2004 (30 students) and Spring 2005 (26 students) semesters, for a total sample size of 56 students. Each student was counted as one experimental unit.

Each subject was randomized into one of two groups: Group 1 wrote five synopsis reports followed by four traditional reports; Group 2 wrote five traditional reports followed by four synopses. Subjects took two examinations: one that covered the content of the first five experiments and one that covered the last four experiments.

Data collection

The instruments used for data collection included a series of nine lab reports from each subject, two exams, composite American College Testing (ACT) [27] scores (gathered from a departmental file), and a survey. Each subject was required to perform nine lab experiments, which were designed to support and enhance the learning of the course content. After each experiment, subjects were allotted one week in which to complete and submit a report based on that experiment. The reports were written in one of the two styles that this study seeks to examine and determined by that subject's random group assignment: synopsis first or traditional first. The exams were given at the transition point (between the fifth and sixth lab experiments) and at the end of the semester. Exam 1 included the topics up to and including Lab 5 and Exam 2 covered Labs 6–9. An end of semester 'exit survey' of attitudes and preferences was administered via WebCT Campus Edition version 4.1 [28].

Assumptions

The participants worked to the best of their abilities on all lab experiments, lab reports, and exams.

The participants were representative of undergraduate industrial technology subjects at Iowa State University.

Concerns about engineering students' written communication skills closely parallel those of students in industrial technology.

An abbreviated lab report format that impinges upon students' learning experience concerning the technology content is desirable to both educators and students in the field of industrial technology.

Limitation

The results of the exit survey, like any survey, could be influenced by student bias; perhaps some students selected their responses based on what they thought the instructor wanted to hear. The potential impact of this bias was reduced by offering no incentive for students to respond in a certain way (including grading incentives), by making survey participation and responses anonymous and voluntary, and by prefacing the survey with a statement that continuous improvement of laboratory instruction requires honest responses.

Delimitations

Only subjects who enrolled in the Fall 2004 and Spring 2005 semesters of ITEC 140, Electrical Fundamentals, were invited to participate in the study.

Data regarding subjects' individual learning styles were neither gathered nor taken into account in the analysis.

Reliability and grading

All instruction and grading was performed by the lead author. The use of grading rubrics provided reliability by ensuring that every lab report with a similar grade represented a comparable level of achievement—traditional reports were graded on content, clarity, completeness, spelling, grammar, correctness of results, and adherence to format; synopsis reports were graded on content, clarity, completeness, spelling, adherence to format, and grammar, but the results of the lab were not considered as a part of the grade (the experiment results were checked for accuracy in the lab and approval by the instructor). The course materials (lecture content, textbook, homework assignments, lab experiments, exam content, and other handouts), as well as the course structure (rules, expectations and requirements, and weighting of graded materials) remained fixed for the duration of the study.

To control instructor bias (positive or negative), every synopsis was graded anonymously by requiring the subjects to format their reports with their name in the upper header—when the reports were clipped into a clipboard for grading, the clip covered the names of the authors. Traditional reports, which had a cover page as a requirement of the format and the lab handout included as the results section, were not assessed anonymously.

Statistical design

All statistical analyses were performed using the SPSS for Windows version 11.0 [29] or JMP version 5.1.2 [30] statistical software packages. To determine if students who wrote synopsis reports learned the content as well as the students who wrote traditional reports, the Latin Square Design, two-sample t-tests (equal variances not assumed), and regression analyses (all using $\alpha = 0.05$) were employed. (Where α = alpha = the chance of a Type I error.) The two-sample t-test was applied to each exam to discover if there were a statistically significant difference in the mean scores between subjects who wrote synopses and subjects who wrote traditional reports on either exam. The Latin Square Design was used to examine the main effects of the two treatments, (synopsis or traditional), the order in which the treatments were administered (synopsis first or traditional first), and the two exams, as well as the effects of the covariates ACT score and the ACT score * (main effect) interactions. Regression analyses were employed to discover how any significant effects of the ACT score covariates affected the students' learning outcomes. The Chi-squared Test of Independence was employed to discover any significant differences between oppositely phrased question pairs on the exit survey.

Results and discussion

A preliminary boxplot analysis of the data set revealed a single outlier in the Group 2 (traditional first), Exam 1 data set—that subject was removed from the data set for the following analyses, which reduced the total number of subjects to 55 (removing the outlier had a negligible effect on the outcome of the statistical analysis). Since students who change majors or transfer from other universities are not required to report their ACT scores for admission into the industrial technology program, the total number of subjects available for the Latin Square Design and regression analyses involving ACT scores was reduced to 47. The range of ACT scores for the sample was 16–29. All of the following data are in units of percent (unless indicated otherwise).

On Exam 1, the mean exam score of synopsis writers was 70.21% and the mean exam score of traditional report writers was 72.69% (see Table 2 and Fig. 1). The two-sample t-test analysis (equal variances not assumed) of Exam 1 revealed no statistically significant difference in mean exam scores between synopsis report writers and traditional report writers ($p = 0.487$, confidence interval = –9.61%; 4.64%). On Exam 2, the mean exam score of synopsis writers was 72.91% and the mean exam score of traditional report writers was 73.54% (see Table 2 and Fig. 2). The two-sample t-test analysis (equal variances not assumed) of Exam 2 revealed no statistically significant difference in mean exam scores between synopsis report writers and traditional report writers ($p = 0.865$, confidence interval = –6.78%; 8.03%).

Regression analysis of the individual exams revealed that ACT scores had a significant effect on students' Exam 1 scores ($F\ (1,46) = 24.657$, $p < 0.001$, B = 2.15%) and Exam 2 scores ($F\ (1,46) = 6.544$, $p = 0.014$, B = 0.585%). (Where B = Beta = slope.) The 95% confidence interval of the regression analysis of Exam 1 revealed that every one point of increase in ACT score resulted in an increase in Exam 1 score between 1.3% and 3.0%, and the 95% confidence interval of the regression analysis of Exam 2 revealed that every one point of increase in ACT score resulted in an increase in Exam 2 score between 0.3% and 2.4%. This indicates that an Iowa State University industrial technology student with an ACT score of 29 could be expected to score between 13% and 30%

Table 2. Exam scores (in percentage correct; $n = 55$)

Exam	Overall		Synopsis		Traditional	
	Mean	Range	Mean	Range	Mean	Range
1	71 38	36.00–94.00	70.21	36.00–92.00	72.69	42.00–94.00
2	73.24	41.30–100.00	72.91	47.83–100.00	73.54	41.30–93.48

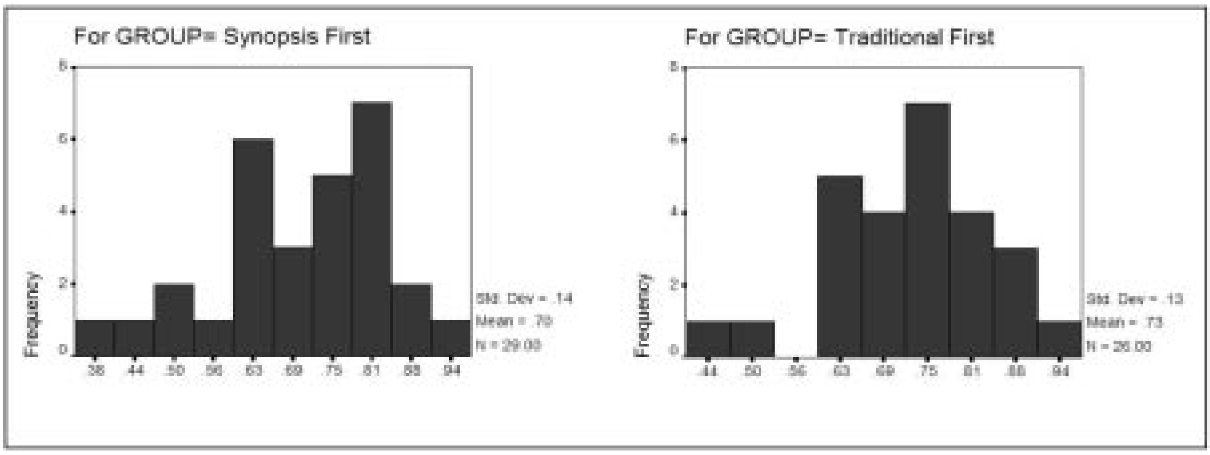

Fig. 1. Histogram for Exam 1 scores (in decimal score).

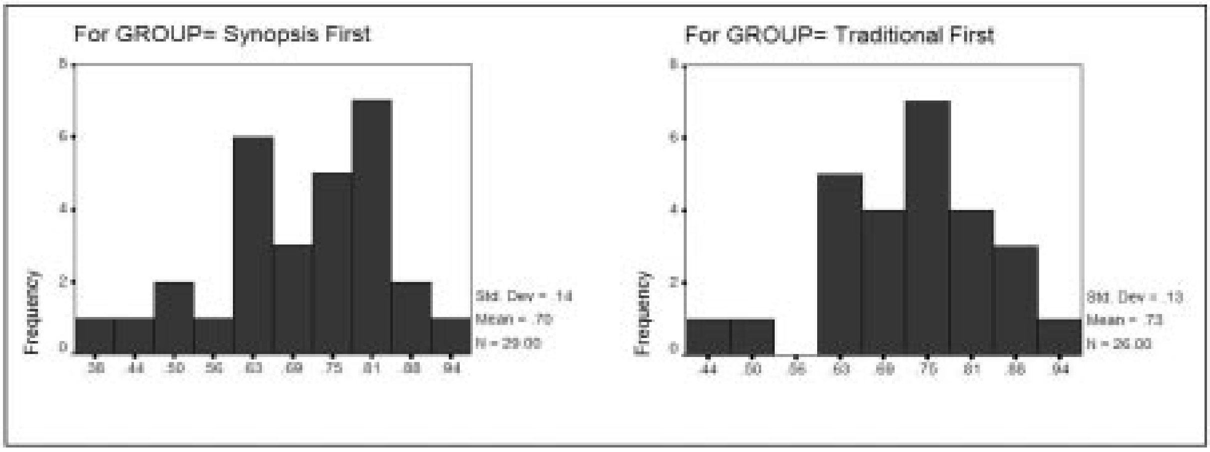

Fig. 2. Histograms for Exam 2 scores (in decimal score).

higher on Exam 1 and between 3% and 24% higher on Exam 2 than a student with an ACT score of 19.

The analysis of variance of the Latin Square Design revealed that the model was significant (F (7,93) = 5.024, p < 0.001), which means that it is appropriate to examine the tests of the main effects and covariates (see Table 3). The test of the factor of interest, the main effect of treatment, revealed that the adjusted least squares mean exam score of synopsis writers was 73.14% and the adjusted least squares mean exam score of traditional report writers was 73.35%, and that these were not significantly different (F (1,93) = 0.0073, p = 0.932, confidence interval = –5.14%; 4.71%). This indicates that the synopsis lab report format had no negative impact on student learning in terms of exam scores. The tests of the nuisance factors order (F (1,93) = 0.1915, p = 0.6628, confidence interval = –3.84%; 6.01%) and exam (F (1,93) = 0.5057, p = 0.4789, confidence interval = –6.69%; 3.16%) were also not significantly different, indicating that the order in which the students wrote the two lab report formats had no effect on their learning as indicated by exam scores, and that students performed similarly on the two exams.

The ACT covariate in the Latin Square Design indicated that ACT scores had a significant association with exam scores (F (1,93) = 30.665, p < 0.001). Regression analysis of the 94 exam scores revealed that every one point of increase in ACT score resulted in an increase in exam scores of between 1.1% and 2.4% (F (1,93) = 26.28, p < 0.001, B = 1.75%); therefore, a student with an ACT score of 29 could be expected to score

Table 3. Effect tests of the Latin Square Design (note: significant effect tests appear in bold)

Source	F	p
Treatment	0.073	0.9320
Order	0.1915	0.6628
Exam	0.5057	0.4789
ACT	**30.6650**	**<0.0001**
ACT*Treatment	0.1230	0.7266
ACT*Order	**6.2363**	**0.0144**
ACT*Exam	1.0644	0.3051

between 11% and 24% higher on exams than a student with an ACT score of 19. The covariate ACT * Order was also significant ($F (1,93) = 6.2363$, $p = 0.0144$); therefore, it can be concluded that ACT scores influenced differing regression patterns between the two groups (synopsis first and traditional first) and perform a regression analysis on the exam scores of each group. The regression analysis of Group 2 indicated no relationship between average exam scores and ACT score ($F (1,46) = 3.220$, $p = 0.087$). The 95% confidence interval of the regression analysis of Group 1 exam scores revealed that every one point of increase in ACT score resulted in an increase in average exam score between 1.6% and 4.0% ($F (1,46) = 24.401$, $p < 0.001$, $B = 2.84\%$); therefore, if a student with an ACT score of 29 writes five synopsis reports followed by four traditional reports, one could expect that student to have an average exam score between 16% and 40% higher than a student with an ACT score of 19. The covariates ACT * Exam ($F (1,93) = 1.0644$, $p = 0.3051$) and ACT * Treatment ($F (1,93) = 0.123$, $p = 0.7266$) were not significant, indicating that ACT scores had no influence on the students' ability to do well between styles of lab reports or between exams.

Regression analyses of the two exams grouped by report type revealed that ACT scores had a significant effect on the exam scores of synopsis report writers ($F (1,46) = 10.326$, $p = 0.002$, $B = 1.61\%$) and traditional report writers ($F (1,46) = 15.927$, $p = < 0.001$, $B = 1.90\%$). The 95% confidence interval of the regression analysis of synopsis report writers' exam scores revealed that every one point of increase in ACT score resulted in an increase in exam score of between 0.6% and 2.6%, and that every one point of increase in ACT score resulted in an increase in exam score between 0.9% and 2.9% for traditional report writers. This indicates that a student with an ACT score of 29 could have been expected to score between 6% and 29% higher on exams when writing synopsis lab reports and between 9% and 29% higher on exams when writing traditional lab reports than a student with an ACT score of 19.

The Latin Square Design and two-sample t-test analyses strongly indicate (with 95% confidence) that the students in the sample who wrote their lab reports in the synopsis format learned the material (as measured by exam scores) just as well as those who wrote their lab reports in the traditional format. It can therefore be assumed that synopsis lab reports would have no negative impact on the learning of industrial technology students if implemented elsewhere in the curriculum. Furthermore, the analyses of ACT covariance indicate that students with higher ACT scores will have a higher probability of higher grades in the Iowa State University industrial technology program.

Forty-two of the 56 subjects involved in the study responded to the WebCT Exit Survey for a response rate of 75%. The results provided useful data about the subjects' preferences between the synopsis and traditional report formats. The respondents were asked to respond on a 5-point Likert scale (strongly disagree [1], disagree [2], neither agree nor disagree [3], agree [4], strongly agree [5]) to eight questions pertaining to preferences and attitudes. The results of the specific survey questions are provided in Table 4. For ease of interpretation, negative responses (1 and 2) and positive responses (4 and 5) were grouped together, and neutral responses (3) were ignored.

An examination of the three pairs of related questions with the Pearson Chi-square Test of Independence revealed statistically significant differences in positive responses between all pairings except questions 5 and 6 (see Table 5). Questions 5 and 6 were not examined because it is reasonable to expect that both lab report formats would yield a perceived improvement in technical writing skills; however, it is worthwhile to point out that the percentage of students who believed the synopsis format helped them improve their technical writing skills is approximately 50% greater than those responding favorably regarding the traditional format.

Table 4. Pertinent exit survey questions and grouped positive and negative response rates

	Question	Negative responses	Positive responses
1	I liked the synopsis report format	7.1	78.6
2	I liked the traditional report format.	52.4	28.6
3	Writing my lab reports in synopsis format helped me to do better on the exam.	7.1	19.0
4	Writing my lab reports in the traditional format helped me to do better on the exam.	28.6	11.9
5	My technical writing skills have improved as a result of writing synopsis lab reports.	9.5	71.4
6	My technical writing skills have improved as a result of writing traditional lab reports.	16.7	47.6
7	I found that the synopsis report format required me to think more deeply about the subject matter.	7.1	64.3
8	I found that the traditional report format required me to think more deeply about the subject matter.	40.5	42.9

Table 5. Paired exit survey questions and the results of the chi-square test of independence analysis

Pairing	P
1 and 2	<0.001
3 and 4	0.039
7 and 8	0.001

CONCLUSIONS AND RECOMMENDATIONS

Based on the results of this study, the following conclusions about student learning (as represented by comprehensive exam scores) can be made with 95% confidence:

- The statistical analyses of exam scores revealed that students who were required to write their laboratory reports in the synopsis format learned the curriculum as well as those who wrote their reports in the traditional format.
  - The type of report had no negative impact on student learning.
  - The order in which students wrote the two report types had no effect on learning.
  - Students performed similarly on the two exams.
- The statistical analyses of composite ACT scores confirmed that higher ACT scores are a good predictor of higher grades in the Iowa State University industrial technology program.
- The analysis of the exit survey with chi-squared tests of independence revealed that:
  - The students preferred the synopsis format to the traditional format.
  - The students perceived that the synopsis format allowed them to score higher on their exams (even though the data analyses do not support this).
  - The students perceived that the synopsis format required them to learn the material at a deeper level. The grader would concur; however, further examination using some criteria such as Bloom's Taxonomy is necessary to determine the actual differences in the level of student learning.
  - The students perceived that they had improved their technical writing skills by writing both types of lab reports.

Based on the findings of these studies, recommendations for future research studies include:

- Repeat this study:
  - at other universities, which will help to confirm or refute the outcomes of this study.
  - in other courses with a laboratory component, which will confirm the effectiveness of the synopsis format in content areas other than *Electrical Fundamentals*.
  - with a larger sample size to increase the power of the statistical analyses and reduce the spread of the confidence intervals.
  - in an engineering curriculum. The curricula and students in the fields of technology and engineering are similar, which makes it worthwhile to establish the effectiveness of the synopsis report format in an engineering curriculum.
- Investigate whether the synopsis lab report format encourages students to develop abilities at higher levels of Bloom's Taxonomy than the traditional format. Hypothetically, the synopsis format requires readers to work at the synthesis level and the traditional format requires students to work at the application level.
- Gather data on students' learning styles using a tool such as the Kolb Learning Style Inventory [31] and investigate relationships between learning styles and the lab report formats, which will establish whether learning styles influence student success on synopsis or traditional reports.
- Investigate the effects of demographic factors such as age, student socio-economic status, first-generation/traditional, underclassman/upperclassman, gender, race, etc., on success with the synopsis format.

Since the synopsis format provides students with an equivalent learning experience to the traditional format, it is worthwhile to consider the additional benefits of the synopsis format, such as reduced instructor grading time and reduced student writing time—Hoffa [32] and Hoffa and Freeman [33] found that not only does the synopsis lab report format free up nearly five hours of students' out-of-class study time for other assignments, but with nine lab reports from 30 students, the synopsis lab report format saves instructors approximately 20 hours of grading time over the course of a semester! The influence of the style of lab report on students' performance on individual lab experiments and mean lab experiment grades is also examined in Hoffa [32].

Acknowledgements—David Hoffa would like to thank his major professor, Steven Freeman, his doctoral committee members: Douglas Bonett, Tom Brumm, Roger Smith, and Susan Yager; Michael Collyer of Iowa State University's Statistical Consulting; and Millersville University's John Wright, Jr.

REFERENCES

1. R. M. Felder and S. A. Peretti, A learning theory-based approach to the undergraduate laboratory, *Proc. ASEE Annual Conference and Exposition*, Session 2413, (June 1998).
2. National Association of Industrial Technology, *2003 Accreditation Handbook*, Author D. Nelson, Ann Arbor, MI, (2003).

3. C. Hart, P. Mulhall, A. Berry, J. Loughran and R. Gunstone, What is the purpose of this experiment? Or can students learn something from doing experiments? *J. Res. in Sci. Teaching*, **37**(7), 2000, pp. 655–675.
4. A. Shapiro, WAC and engineering, or why engineers can't write. Paper presented at the 42nd Annual Meeting of the Conference on College Composition and Communication, Boston, MA, ERIC Document Reproduction Service No. ED332199, (21 May, 1991).
5. D. V. Connor, Effectiveness of teaching methods at the university level, *Tertiary Education Res. Centre Bull*, 7, ERIC Document Reproduction Service No. ED175329, New South Wales University, Kensington, Australia, (1977).
6. D. Gillet, H. A. Latchman, C. Salzmann and O. D. Crisalle, Hands-on laboratory experiments in flexible and distance learning, *J. Engineering Education*, **90**(2), 2001, pp. 187–191.
7. N. G. Lederman, Teachers' understanding of the nature of science and classroom practice: Factors that facilitate or impede the relationship, *J. Res. Sci. Teaching*, **36**(8), 1999, pp. 916–929.
8. H. Drury, P. O'Carroll and T. Langrish, Online approach to teaching report writing in chemical engineering: Implementation and evaluation, *Int. J. Engineering Education*, **22**(1), 2006.
9. J. Doumont, Effective executive summaries: A simple but effective paradigm, *Proc. IEEE Int. Professional Communication Conference*, (September 2003), pp. 166–169.
10. B. S. Bloom, *Taxonomy of Educational Objectives,* David McKay Company, New York, (1956).
11. G. Krumme, Major categories in the taxonomy of educational objectives, http://faculty.washington.edu/krumme/guides/bloom.html, (15 September 2005).
12. J. R. Wright, Jr., E-mail correspondence with the author, (25 August, 2005).
13. C. Plumb and C. Scott, Outcomes assessment of engineering writing at the university of Washington, *J. Eng. Education*, **91**(3), 2002, pp. 333–338.
14. J. Williams, Transformations in technical communication pedagogy: Engineering: Writing and the ABET Engineering Criteria 2000, *Technical Communication Quarterly*, **10**, 2002, pp. 149–168.
15. P. Sageev and C. J. Romanowski, A message from recent engineering undergraduates in the workplace: Results of a survey on technical communication skills,-. *J. Eng. Education*, **90**(4), 2001, pp. 685–692.
16. A. Keane and I. S. Gibson, Communication trends in engineering firms: implications for undergraduate engineering courses. *Int. J. Eng. Education*, **15**(2), 1999, pp. 115–121.
17. E. Wheeler and R. L. McDonald, Writing in engineering courses, *J. Eng. Education*, **89**(4), 2000, pp. 481–509.
18. C. Friday, An evaluation of grading engineers writing proficiency, *J. Eng. Education*, **77**(2), 1986, pp. 114–116.
19. A. Nixon, and G. Fischer, Developing an appropriate writing exercise for a statics class, *Proc. 31st ASEE/IEEE Frontiers in Education Conference*, T2G-4, (October 2001).
20. J. Doumont, Developing real-world communication skills in non-communication classrooms, *Proc. IEEE Int. Professional Communication Conference*, (September 2002) pp. 138–144.
21. R. Baren and J. Watson, Developing communication skills in engineering classes, *Proc. 1993* Int. *Professional Communication Conference*, (October 1993) pp. 432–437.
22. C. Boiarsky, Teaching engineering students to communicate effectively: a metacognitive approach, *Int. J. Engineering Education*, **20**(2), 2004, pp. 251–260..
23. M. Lima, C. M. Drapcho, T. H. Walker, R. L. Bengtson and L. R. Verma, A model for integrating skills across the biological engineering curriculum, *Int. J. Engineering Education*, **17**(1), 2003, pp. 67–74.
24. C. Brewster and J. Klump, Writing to learn, learning to write: revisiting writing across the curriculum in Northwest secondary schools, by request, Northwest Regional Educational Laboratory, Portland, OR, (December, 2004).
25. J. Romberger, Writing across the curriculum and writing in the disciplines, http://owl.english.purdue.edu/handouts/WAC, (13 September 2005).
26. G. Boyd and M. F. Hassett, Developing critical writing skills in engineering and technology students, *J. Engineering Education*, **89**(4), 2000, pp. 409–412..
27. American College Testing, http://www.act.org, (14 December 2005),
28. WebCT, WebCT Campus Edition, http://www.webct.com/software/viewpage?name= software_campus_edition, (19 September 2005).
29. SPSS, SPSS Family of Statistical Software, Data Collection Software, and Survey Research Software, http://www.spss.com/spss/family.cfm?source=homepage &hpzone=tech, (19 September 2005).
30. SAS Institute, JMP Software, http://www.jmp.com, (27 October 2005).
31. A. Y. Kolb and D. A. Kolb, The Kolb learning style inventory version 3.1: 2005 technical specifications, http://www.learningfromexperience.com/images/uploads/Tech_spec_LSI .pdf, (22 November 2005).
32. D. W. Hoffa, Synopsis laboratory reports: effects on student learning and curricular benefits, unpublished doctoral dissertation, Iowa State University, Ames.
33. D. W. Hoffa and S. A. Freeman, Reducing student writing time and instructor grading time of laboratory reports *J. of Industrial Technology* **22**(3), 2006, pp. 1–5. http://www.nait.org/jit/Articles/hoffa092006.pdf (September 27, 2006).

David W. Hoffa is the proprietor of David Hoffa Industrial Consulting and a Quality Engineer at Accumold in Ankeny, Iowa. He holds a Ph.D. in Industrial Technology from Iowa State University, a Master of Science in Electronics and Computer Technology from Indiana State University, and a Bachelor of Science in Industrial Technology from Millersville University of Pennsylvania. He is the recipient of the 2005 NAIT Foundation Dr. Clois E. Kicklighter Doctoral Student Scholarship Award.

Steven Freeman is an Associate Professor in Iowa State University's Department of Agricultural and Biosystems Engineering and the Assistant Director of the Center for Excellence in Learning and Teaching. He coordinates the department's occupational safety program and conducts research in occupational safety as well as the scholarship of teaching and learning.